Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2020-28-RC2, 2020

Annales Geophysicae Discussions

Interactive comment on "Radar Imaging with EISCAT 3D" *by* Johann Stamm et al.

Anonymous Referee #2

Received and published: 2 August 2020

The present manuscript analyzes the problem of radar imaging in 3D for incoherent scatter applications that will be implemented using the EISCAT 3D radar. It is mentioned that the proposed technique includes "near field" effects on the formulation of the radar imaging problem because EISCAT 3D applications will be in such regime. The analysis includes also the concept of MIMO radars in order to improve the resolution of radar images. The manuscript is well organized and the results are presented clearly. Although the analysis performed in this document introduces new ideas related to the radar imaging problem, I would recommend a careful revision of the document before its possible publication. As I will explain there are some important issues that have to be addressed first.

1. In Equation 2 (page 5), it is assumed that the number of independent measurements per second is proportional to the number of lagged products in a longpulse experiment. This is definitely not the case. In a long pulse experiment, lag products are not indepen-

Printer-friendly version

Discussion paper

dent, all of them are correlated. This is because, within the length of a pulse, signals from a common volume are mixed. Assuming that all lag products are equally informative, it is also an oversimplification that I think may lead to not necessarily correct conclusions, particularly, in this application in which the target fills the radar volumen. I would recommend the authors to review this section in order to analyze more carefully the relationship between the number of samples within a longpulse and the integration time needed to reduce statistical uncertainty. Notice that if you consider Np=1, there is a singularity in equation (7), I don't think this is correct. I would also recommend to review equation 11 since a radar volume can be modeled better as a spherical cone section rather than as a truncated cone. In this expression, if you consider "r" at the center of the radar volume, the expression becomes simplified.

2. In the introduction (line 22, page 4), it is mentioned that there is not much literature related to 3D imaging and the authors make reference to a recent work of one of the coauthors. This is not fully true, the works of Palmer et al(1998), Yu et al (2000), and Chau & Woodman (2001) (see references below) addressed the imaging problem in 3D in the same sense as the present manuscript does. Of course the difference is that the new approach is addressing the incoherent scatter problem while the previous work was mainly focussed on coherent scatter echoes. So proper references should be used.

3. In line 29, page 7, the integration time for MIMO applications is analyzed and it is mentioned that the integration time will be longer in the MIMO case than in the SIMO case, but the authors indicate that the difference depends on cross-coupling between antennas. I don't think this conclusion is correct, at least not as a first approximation. There is plenty of literature related to soft-target radar equations that explain clearly that the received power is directly proportional to an effective antenna aperture area (which is also proportional to the true antena area). So, even if you use the same power on transmission, the received power will be less when using a small antenna. Then, the need for additional integrations in the MIMO case is di-

rectly related to the fact that smaller antennas will be used, less power will be detected and SNR will be smaller. Cross-coupling may have an additional role but that is definitely a second order effect. I would recommend to review Radar Principles by Toru Sato. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19910017301.pdf I would also recommend to review the work of Woodman(1991) which is very related to the type of analysis performed in this work.

4. In the discussion about the baseline cross-correlation, it is not clear why equations 20 and 23 (pages 10 and 11) should give different results. Both expressions come from taking the Fourier transform of a gaussian blow. It seems the difference comes from a different interpretation of the geometry. So, if the same interpretation is given both results (the far field and near field expressions) should be the same. Then, let me ask what the "near field" effects are.

In fact, let me mention the following. In the work of Woodman (1997), it is argued that the near field effect can be modeled as a phase correction in the visibility domain, however, in the present manuscript the near field effect is not presented as a phase correction but as a change of the magnitude of the visibility (correlation) function. Given the different interpretation of the near field effects, I should ask again if the there is actually a "near field" effect that has to be considered in radar imaging problems.

Let me add one more detail. Woodman(1991) derives an expression for the cross-correlation between the voltages of two different antennas showing that the cross-correlation is equal to the Fourier transform of a Brightness function to a second order approximation. In this derivation, there was no need to match the Fraunhofer condition, it was enough that the radar range should be much greater than the separation between the antennas (R»D). This result was actually a generalization of an earlier result presented by Kudeki(1990).

This is a very important issue that needs to be reviewed more carefully in this manuscript. Since it is argued that "near field" effects are considered, the authors should show clearly what these effects are. However, based on previous literature, it seems that the Fourier transform approximation is good enough for the EISCAT 3D scenario. If that is the case, the problem presented in the manuscript gets simplified and the results presented can be obtained without a complicated framework.

R. D. Palmer, S. Gopalam, and T.-Y. Yu, "Coherent radar imaging using capon's method," Radio Science, vol. 33, pp. 1585–1598, November-December 1998.

T.-Y. Yu, R. D. Palmer, and D. L. Hysell, "A simulation study of coherent radar imaging," Radio Science, vol. 35, pp. 1129–1141, September-October 2000.

J. L. Chau and R. F. Woodman, "Three-dimensional coherent radar imaging at Jicamarca: comparison of different inversion techniques," Journal of Atmospheric and Solar-Terrestrial Physics, vol. 63, no. 2-3, pp. 253–261, 2001.

R. F. Woodman, "A general statistical instrument theory of atmospheric and ionospheric radars," Journal of Geophysical Research, vol. 96, pp. 7911–7928, May 1991.

Kudeki, E., Sürücü, F., and Woodman, R. F. (1990), Mesospheric wind and aspect sensitivity measurements at Jicamarca using radar interferometry and poststatistics steering techniques, Radio Sci., 25(4), 595– 612, doi:10.1029/RS025i004p00595.

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2020-28, 2020.